Ocean Engineering 96 (2015) 284–294

Contents lists available at ScienceDirect

Ocean Engineering

journal homepage: www.elsevier.com/locate/oceaneng

Spatial analyses of 52 years of modelled sea state data for the Western Baltic Sea and their potential applicability for offshore and nearshore construction purposes

Marcus Siewert*, Christian Schlamkow, Fokke Saathoff

Universität Rostock, Chair of Geotechnics and Coastal Engineering, Justus-von-Liebig Weg 6, LAG II, 18059 Rostock, Germany

ARTICLE INFO

Article history:
Received 19 February 2014
Accepted 20 December 2014
Available online 30 January 2015

Keywords:
Wave statistics
Sea state analysis
Spatial distribution
Baltic Sea

ABSTRACT

The present paper contains statistical analysis of modelled sea state data for the Western Baltic Sea for a time period of 52 years. Twenty charts were created, showing mean wave heights and frequencies of occurrence for different seasons. Taking a closer look at three potential areas for offshore wind energy in the Western Baltic the following mean significant wave heights were calculated (from west to east): Fehmarnbelt 0.6 m, Kadet Furrow 0.7 m and Arkona Basin 0.9 m. A comparison with waverider buoy measurements at five locations for different time series proves the good quality of the modelled data. These charts impart detailed information on the sea state from a spatial and temporal perspective which can be utilized by a wide range of users from different backgrounds. An exemplary monthly analysis of one location shows the possible application of the data set.

1. Introduction

Sea state data is a governing parameter for the dimensioning of coastal protection structures (dikes and dunes) or harbor facilities. Therefore, the sea state is usually calculated for a small specific area, a line of points, or one single point. The growing market of offshore activities leads to a growing demand for spatial sea state data for the open sea. Wave spectra have been investigated for years and are a common tool for describing the sea state (Pierson and Moskowitz, 1964; Hasselmann et al., 1973). Still, they give no information about the spatial variability of the sea state. There are several publications that deal with sea state and wave heights in the Baltic Sea with different regional focus and different analysis methods (Schmager, 1979; Blomgren et al., 2001; Augustin, 2005; Cieślikiewicz and Paplińska-Swerpel, 2008; Feistel et al., 2008; Soomere et al., 2012). Numerical simulations and measurement campaigns have been carried out for different regions of the Baltic Sea and for different time scales. The way of presenting the analyses differs from single point analyses to spatial analyses for specific regions at different scales. No detailed spatial analyses have been made for the Western Baltic Sea until now. The Western Baltic Sea is highly frequented by ships (sailing boats, commercial fishing vessels, container ships, ferries, cruise ships and oil tankers) with no pilot obligation, but narrow and shallow shipping lanes and a growing number of offshore wind farms. Detailed spatial information on sea state conditions for different seasons in this region can be used by many users and gives an essential upgrade to the nautical security in this area.

Subsequently, spatial sea state data of the Western Baltic Sea is statistically analyzed and plotted to charts. For the statistical analysis a 52-year data set covering the period 1948 to 1999 was used. Different statistical parameters have been chosen to show characteristic values of the sea state data (mean significant wave height and the frequencies of occurrence for waves with minimum height of 0.5 m, 1.0 m and 1.5 m). The calculations have been made for the whole time series and for different seasons (winter, spring, summer and autumn).

This data analysis is part of the research project "BioBind" which is funded by the German Federal Ministry of Economics and Technology. The aim of the project BioBind is to develop an effective and fast airborne oil spill recovery system for nearshore shallow water areas and adverse weather conditions by using biogenic binders. Oil spill response equipment is highly sea state dependent, therefore it is necessary to have a detailed knowledge on the spatial distribution of sea state data to guarantee an effective oil spill response by choosing the appropriate equipment. In this context it was decided to analyze sea state data to evaluate the performance and application limits of spill response equipment.

The Baltic Sea is a landlocked intercontinental sea in Western Europe which is dominated by wind waves which are fetch-limited.

* Corresponding author. Tel.: +49 381 4983689.
E-mail addresses: marcus.siewert@uni-rostock.de (M. Siewert), christian.schlamkow@uni-rostock.de (C. Schlamkow), fokke.saathoff@uni-rostock.de (F. Saathoff).

http://dx.doi.org/10.1016/j.oceaneng.2014.12.029
0029-8018/

The spatial distribution of wave heights in the Western Baltic Sea is a result of two special features:

1. Winds from westerly directions (southwest is the dominating direction) are the main energy input for the sea state in this region. The longer the fetch length is, the bigger the waves are. Thereby the wave heights increase from west to east.
2. Winds from easterly directions (less frequent) can have a very long fetch length ($x > 600$ km) and generate high wave heights. These waves travel to the southwestern end of the Baltic Sea and bring even more energy to the areas with high waves heights due to the west wind input (Arkona Basin (e)). For increasing the mean wave heights in the Bay of Lübeck (c) these events are too seldom.

In Fig. 1 the frequencies for wind from different directions at the location Rostock–Warnemünde (situated at the southern coast of Western Baltic Sea) between 1996 and 2005 are shown. Nearly 45% of the wind is coming from directions between 210° and 300°.

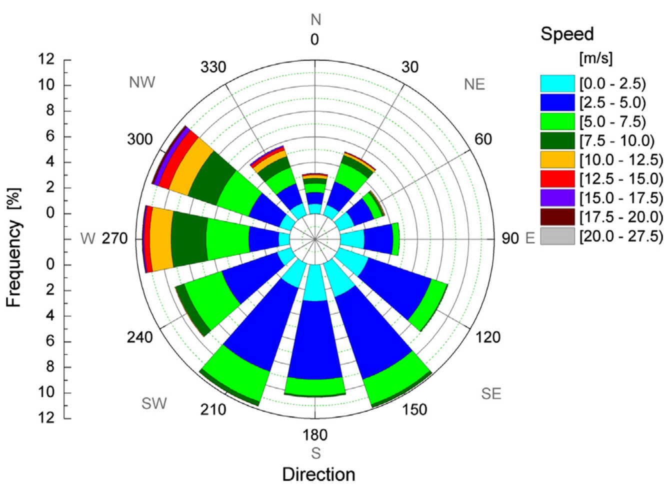

Fig. 1. Frequency of occurrence of wind for the western Baltic at Rostock–Warnemünde (1996–2005).

This strongly influences the creation and propagation of waves in the Western Baltic.

2. Methodology

2.1. Data basis

The data basis for the statistical analysis is a result of different consecutive research projects conducted recently. The wind data was taken from the EU-funded research project HIPOCAS—Hindcast of Dynamic Processes of the Ocean and Coastal Areas of Europe (Feser et al., 2001; Soares et al., 2002). Within this research project the regional atmospheric model REMO was used, driven by the global reanalysis of the National Center for Environmental Prediction, to determine a hindcast of wind velocities for a wide area of northern Europe (Fig. 2). The wind data covered the area from 9.5–22°E to 53.5–58°N with a spatial resolution of $\Delta x \approx 0.5°$ and $\Delta y \approx 0.5°$.

The wave heights were taken from the project MUSTOK. In the project MUSTOK—Modeling of Extreme Storm Surges on the German Baltic Sea Coastline (Jensen, 2009), funded by the German Federal Ministry of Education and Research, different models have been used to determine extreme values for sea state as well as water levels for specific locations along the German Baltic Sea coastline. Within the sub-project SEBOK B wind data from the HIPOCAS project was used to calculate hourly significant wave heights for the German Baltic Sea area (Schlamkow and Fröhle, 2009). The sea state simulation was performed using the sea state model SWAN (Booij et al., 2001; The SWAN Team, 2011). For the SWAN simulations a bathymetry of the Baltic Sea with a spatial resolution of $\Delta x \approx \Delta y \approx 1$ nm was used (Fig. 2) (Seifert et al., 2001). As a combination of the modelled area (Southern Baltic) and the used input data (HIPOCAS) the model was called SOHIP.

2.2. Accuracy of modelled data

To evaluate the SOHIP simulation, the modelled sea state data were compared to wave measurements performed by University of Rostock in recent years (Fröhle, 2000) (except station Darss Sill which is operated by the Helmholz Zentrum Geesthacht Centre for

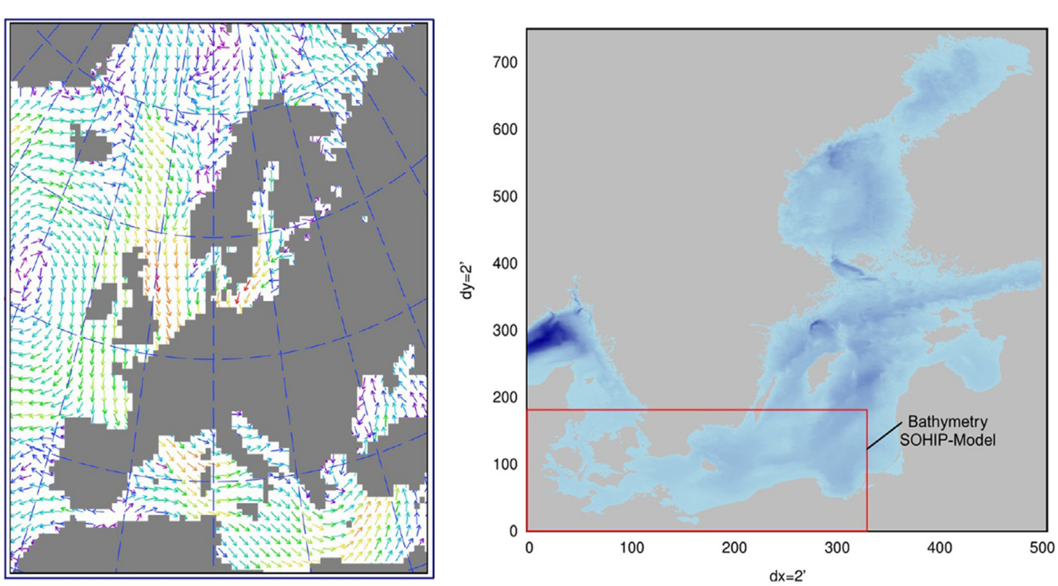

Fig. 2. Spatial extension of wind data within the HIPOCAS project (left, Weisse and Günther, 2007), Baltic Sea bathymetry and boundaries of the SOHIP model (right, Schlamkow and Fröhle, 2009).